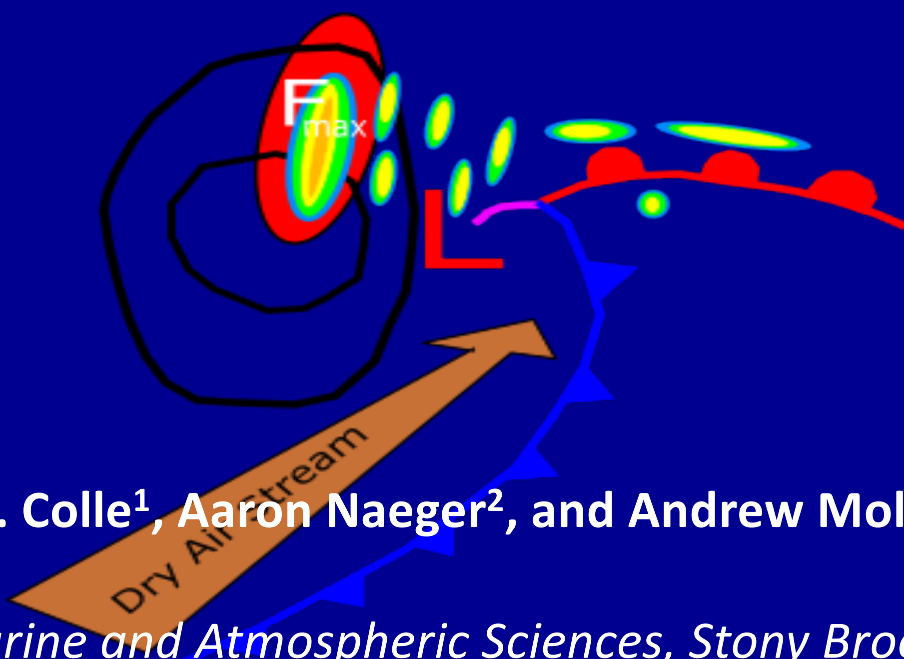
Warm Frontal Snowband Evolution and Microphysical Validation During GPM Cold Season Precipitation Experiment (GCPEx)



Brian A. Colle[1], Aaron Naeger[2], and Andrew Molthan[3]

1.School of Marine and Atmospheric Sciences, Stony Brook University

2. University of Alabama at Huntsville

3. NASA Marshall Space Flight Center, Huntsville, AL

Stony Brook University School *of* Marine and Atmospheric Sciences

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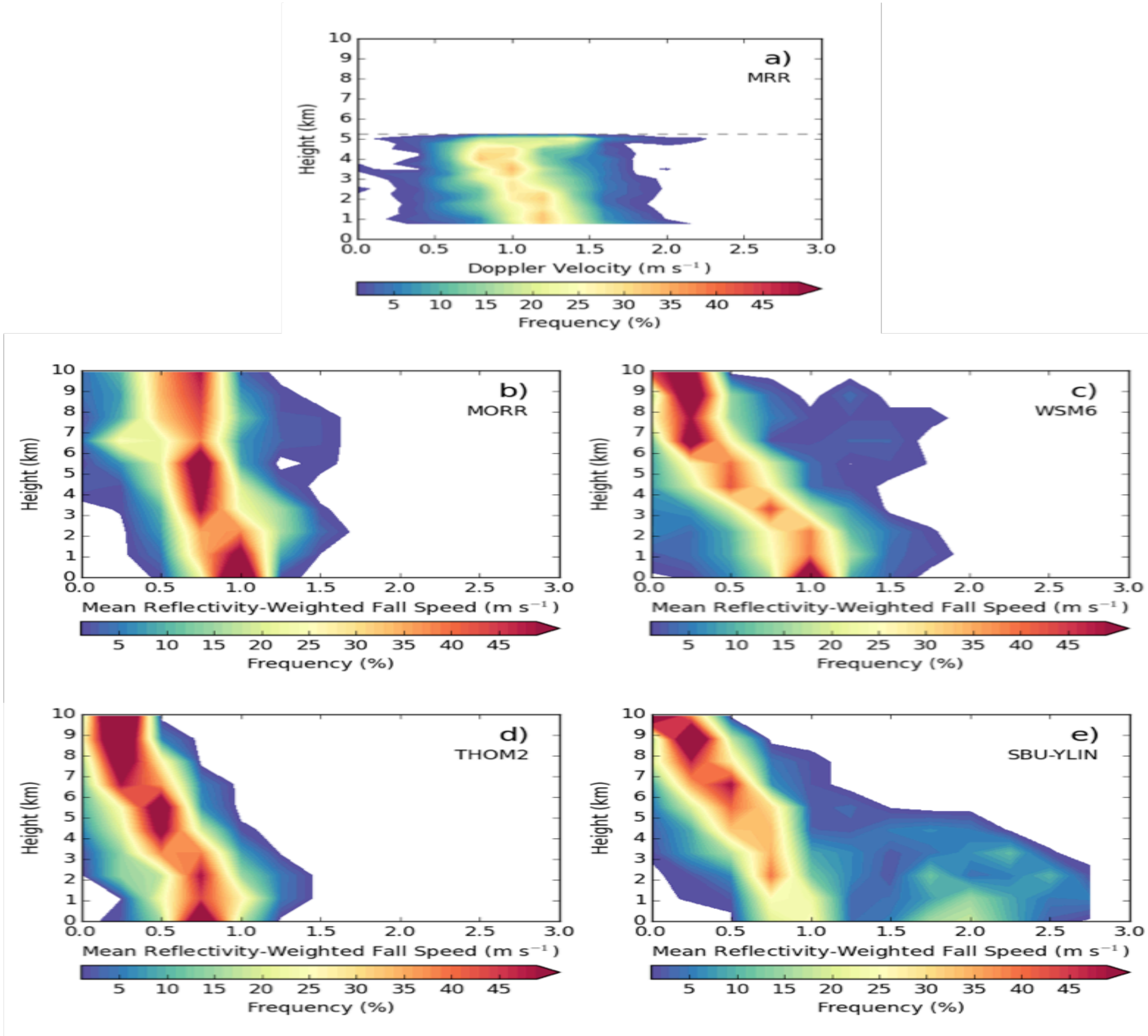
Motivation

• Increasing evidence that bulk microphysical schemes in mesoscale models underpredict riming within winter storms.



Simulations of 9 winter storms over Long Island, NY highlights underprediction of snow fallspeeds during moderate riming conditions as compared to MRR measurements.

Molthan et al. (MWR 2016)

Some Questions

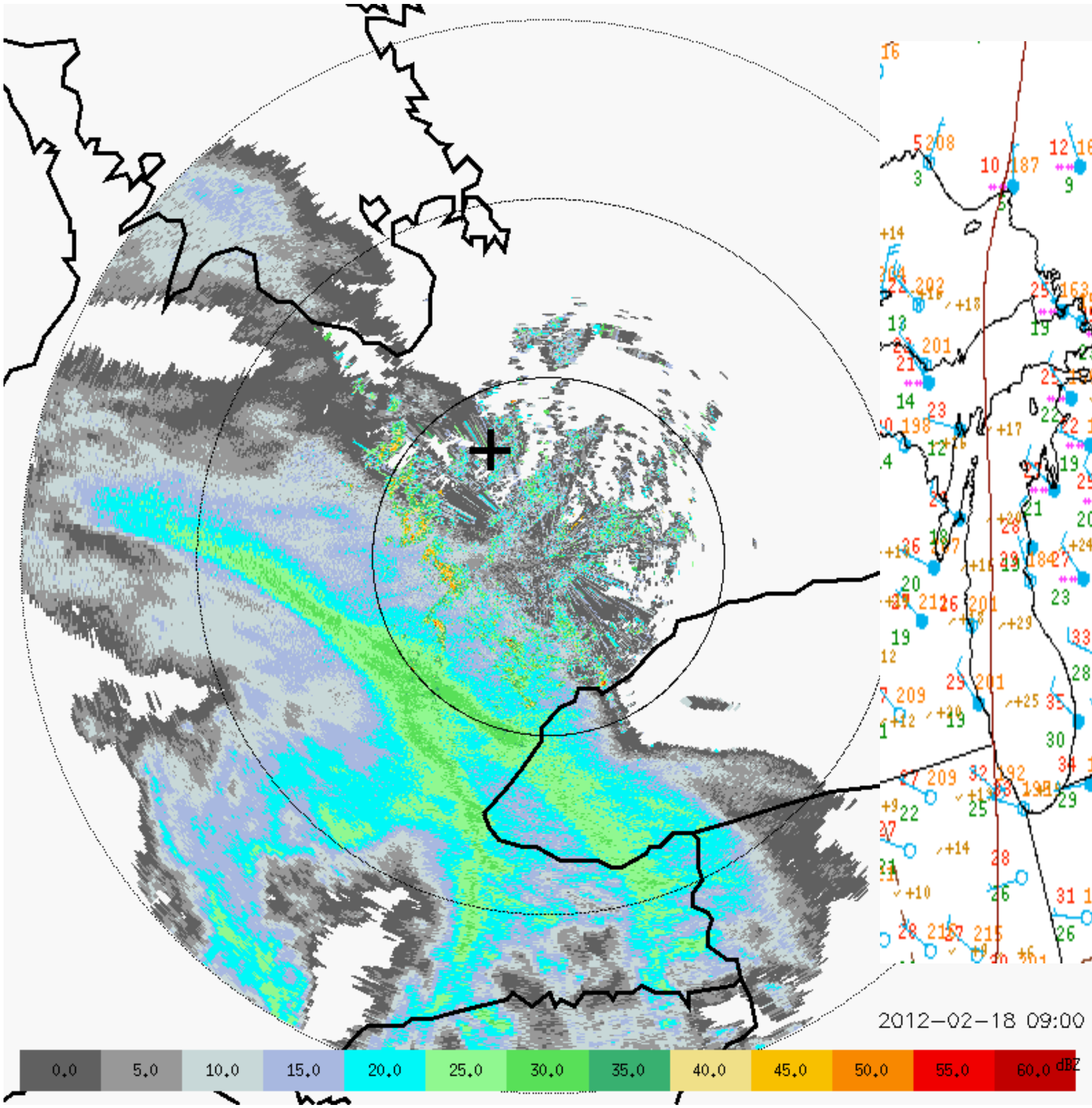
- What processes led to the rapid intensification and microphysical changes of the warm frontal precipitation band (Colle et al. MWR 2016)?

- How well can current, more advanced BMPs (i.e, P3, Goddard 4ICE, SBU, and Morrison) predict the warm frontal band development and riming intensity for this event?

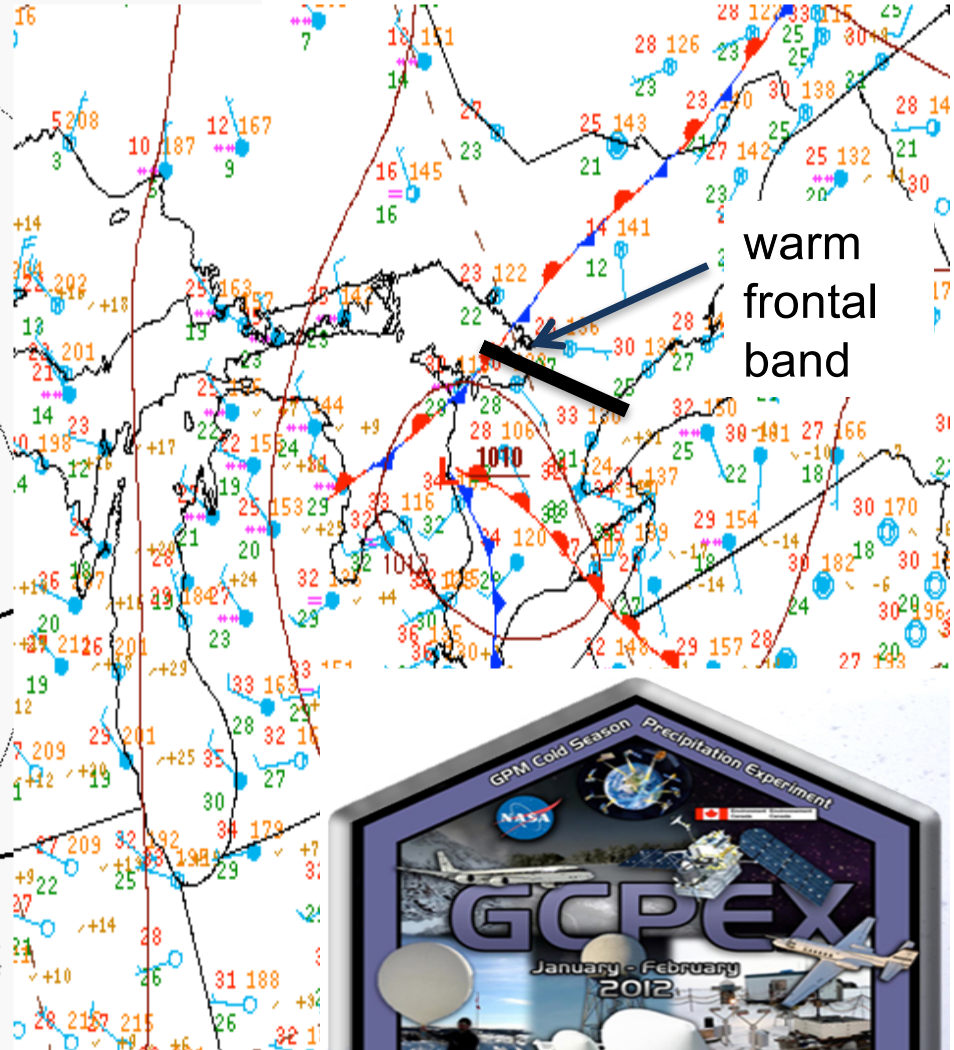
- How do cloud microphysical processes modify the environmental conditions and the subsequent warm frontal band development?

Warm Frontal Band During GCPEx

18 February 2012: King City Radar Animation

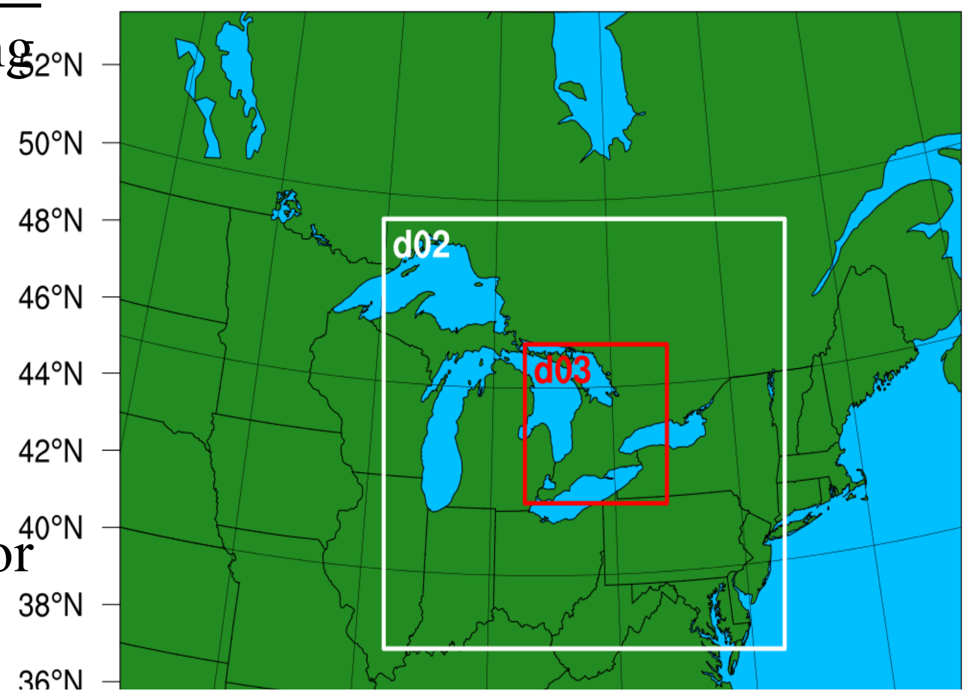


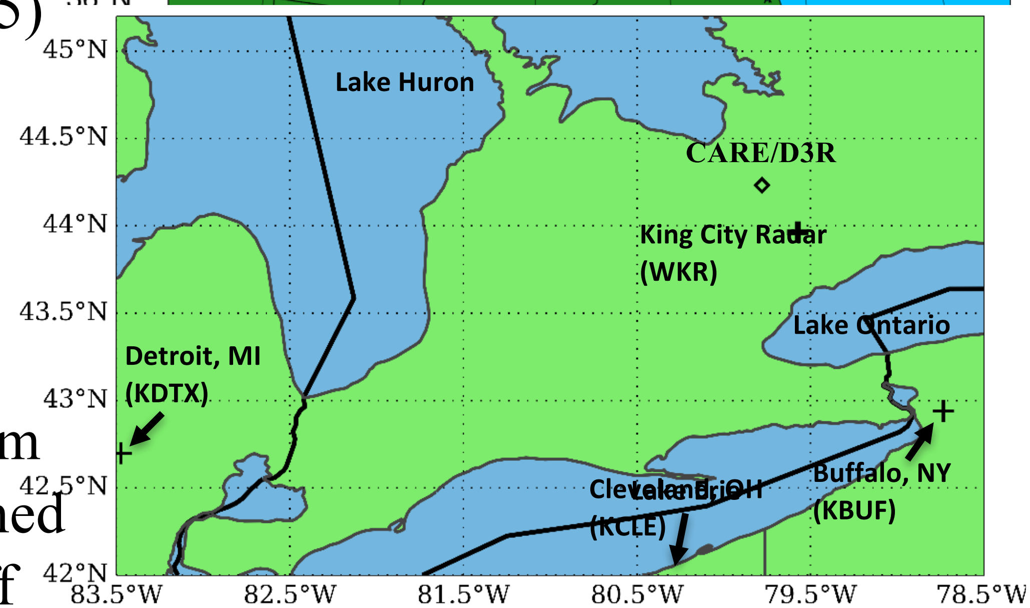
1200 UTC NWS Surface Analysis

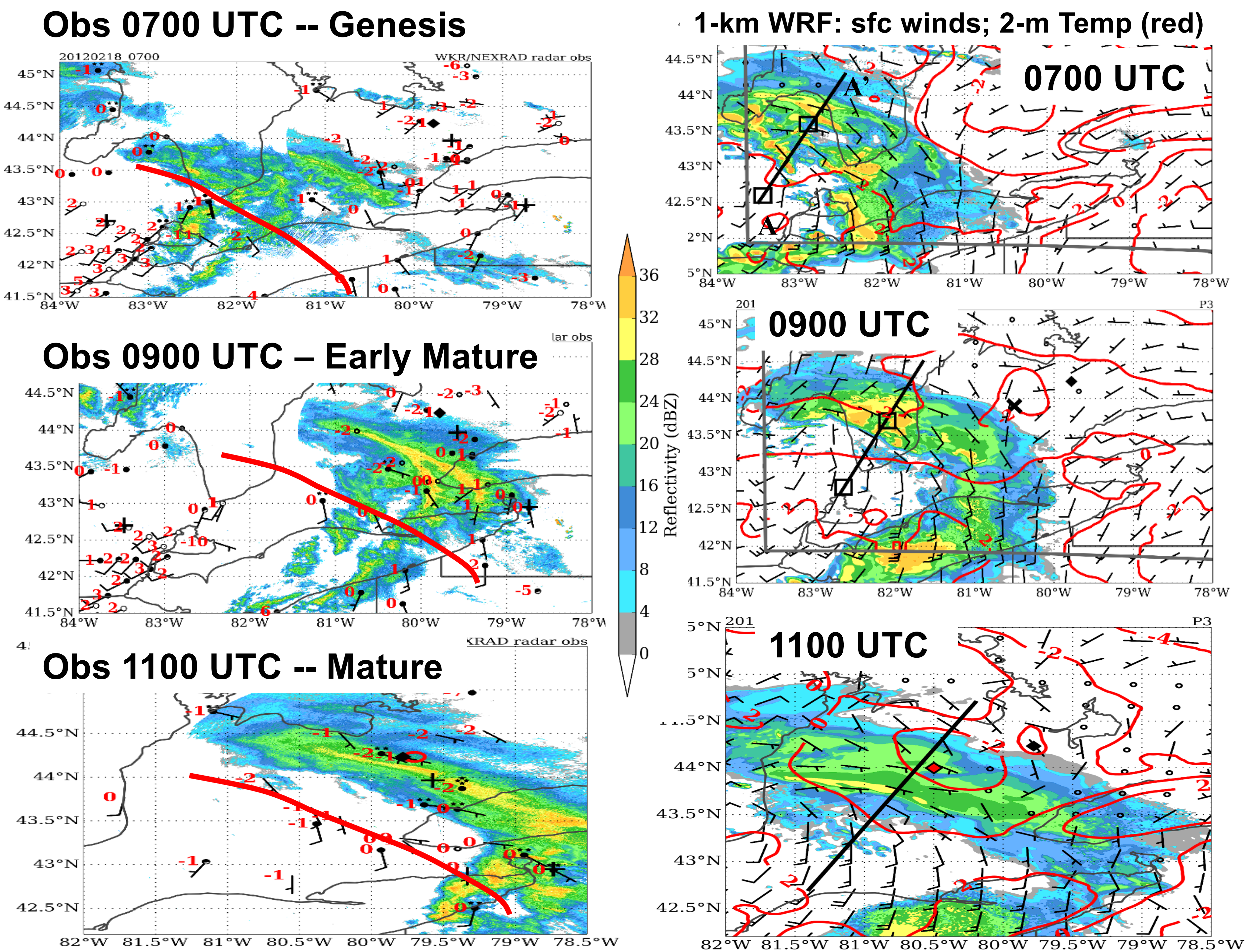


Weather Research and Forecasting Simulations

NASA-Unified-WRF configuration			
IC and Boundary Conditions	6-h RUC Analyses starting 1800 UTC 17 Feb (30-h run)		
Vertical Resolution	50 Levels		
PBL Physics	Mellor-Yamada-Janjic		
Cloud microphysics P3 introduces a prognostic rime growth variable	Predicted Particle Properties (P3) scheme for CTL run (Morrison et al. (2015)		
Short- and Longwave Radiation	RRTMG		
Horizonal Resolution	9 km	3 km	1 km
Cumulus scheme	Grell-Freitas	Turned off	Turned off

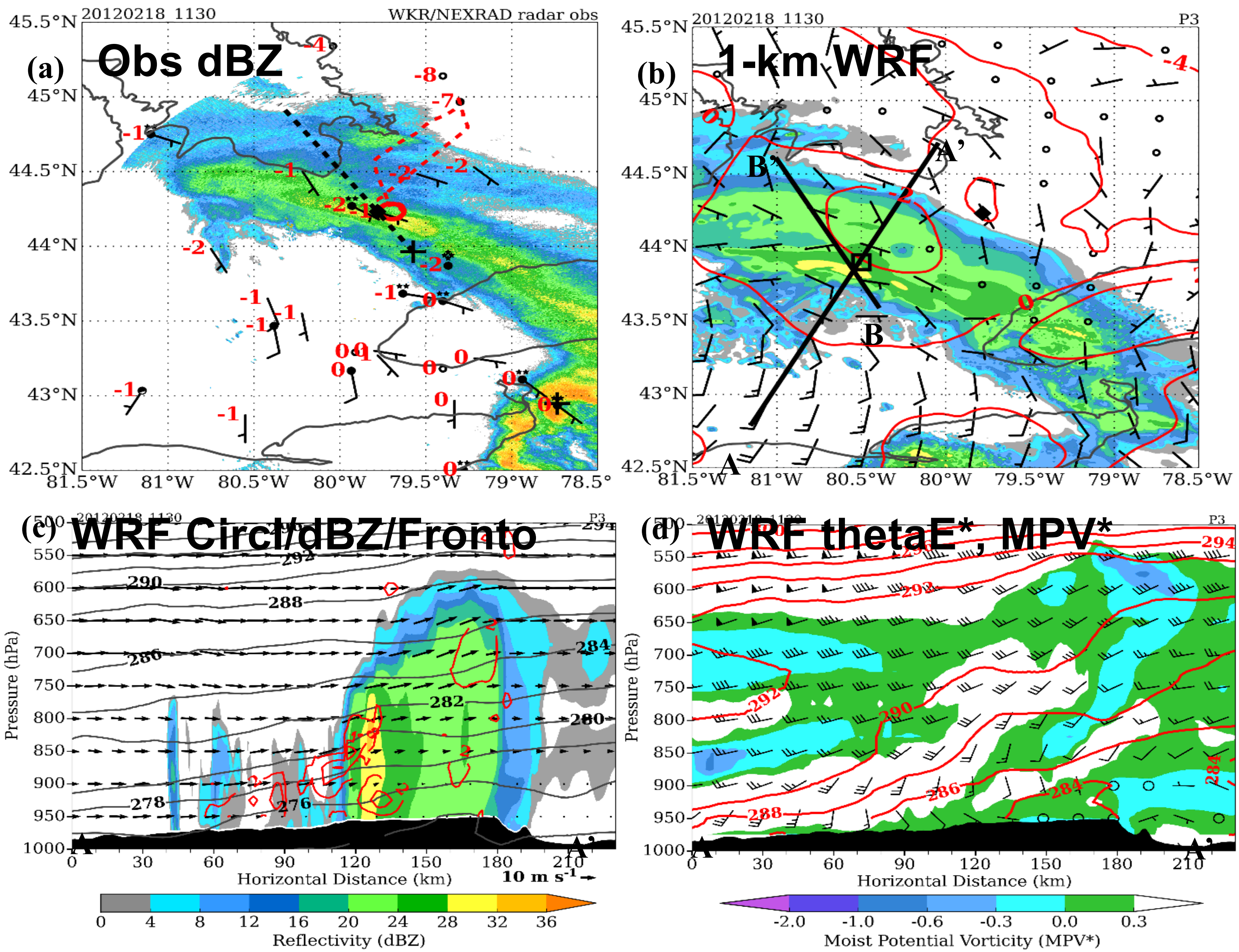




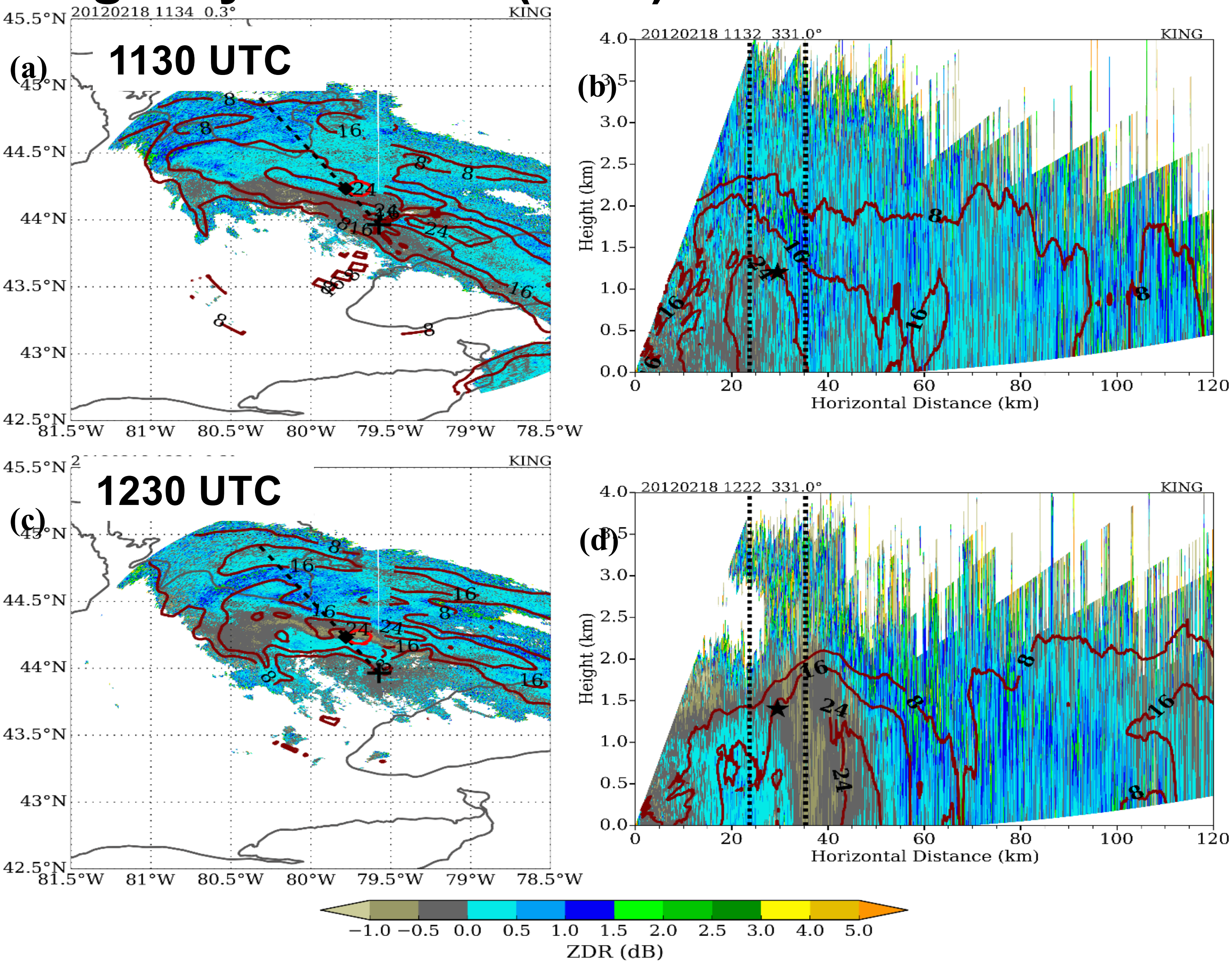


Obs 0700 UTC -- Genesis
20120218_0700
WKR/NEXRAD radar obs
Obs 0900 UTC – Early Mature
Obs 1100 UTC -- Mature
1-km WRF: sfc winds; 2-m Temp (red)
0700 UTC
0900 UTC
1100 UTC
A
A'
Reflectivity (dBZ)
36
32
28
24
20
16
12
8
4
0
84°W
83°W
82°W
81°W
80°W
79°W
78°W
81.5°W
80.5°W
79.5°W
78.5°W
45°N
44.5°N
44°N
43.5°N
43°N
42.5°N
42°N
41.5°N

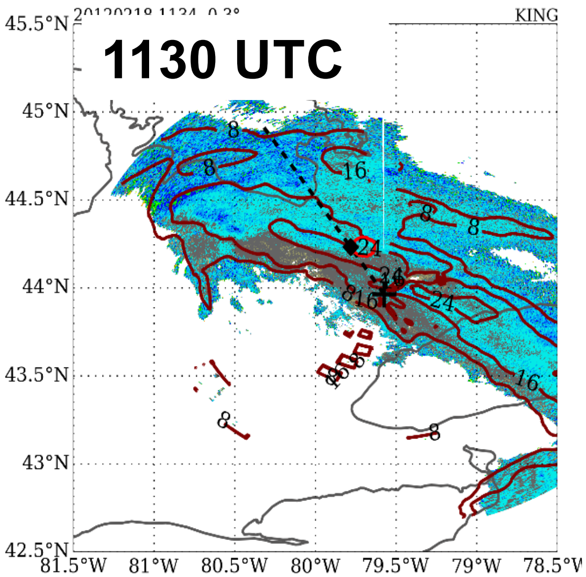
Forcing and Stability for Frontal Band (1130 UTC)

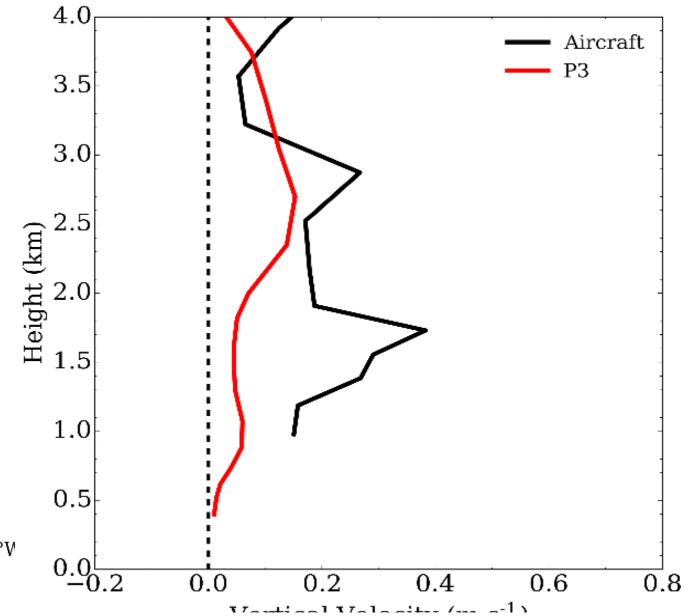


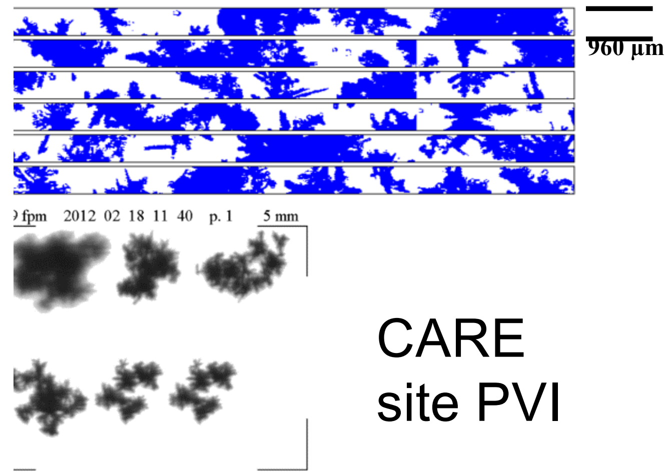
King City Dual Pol (ZDR) Obs of Frontal Band



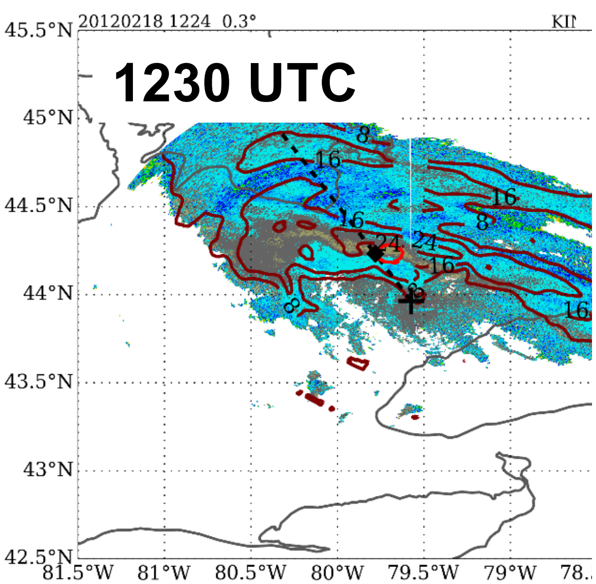
Ice Microphysics for North (top) v. South (bottom) Part of Band

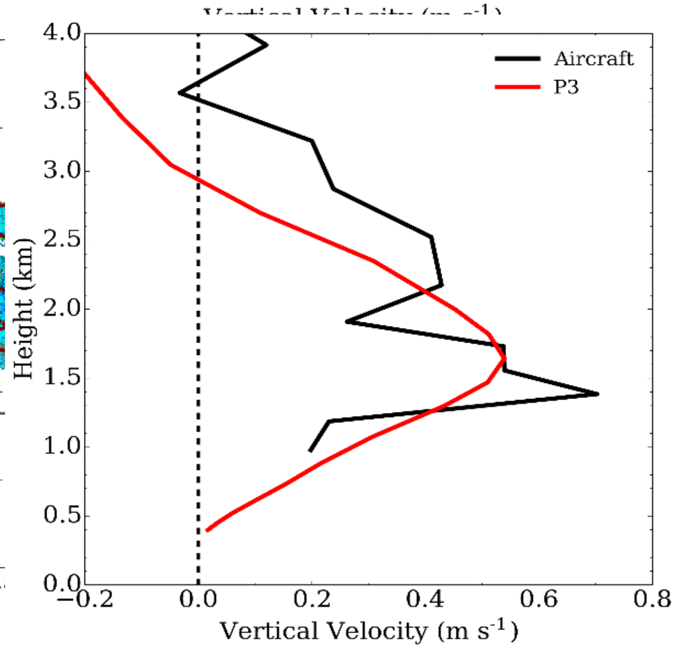


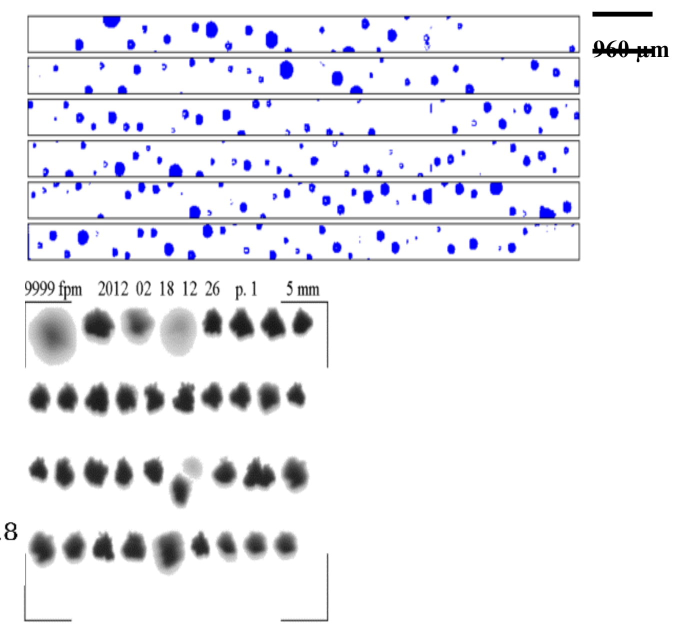




CARE
site PVI





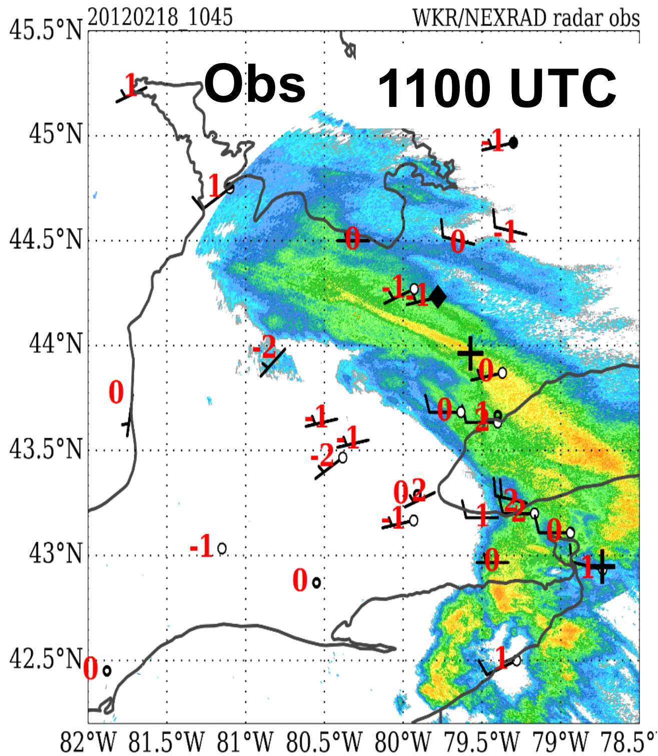


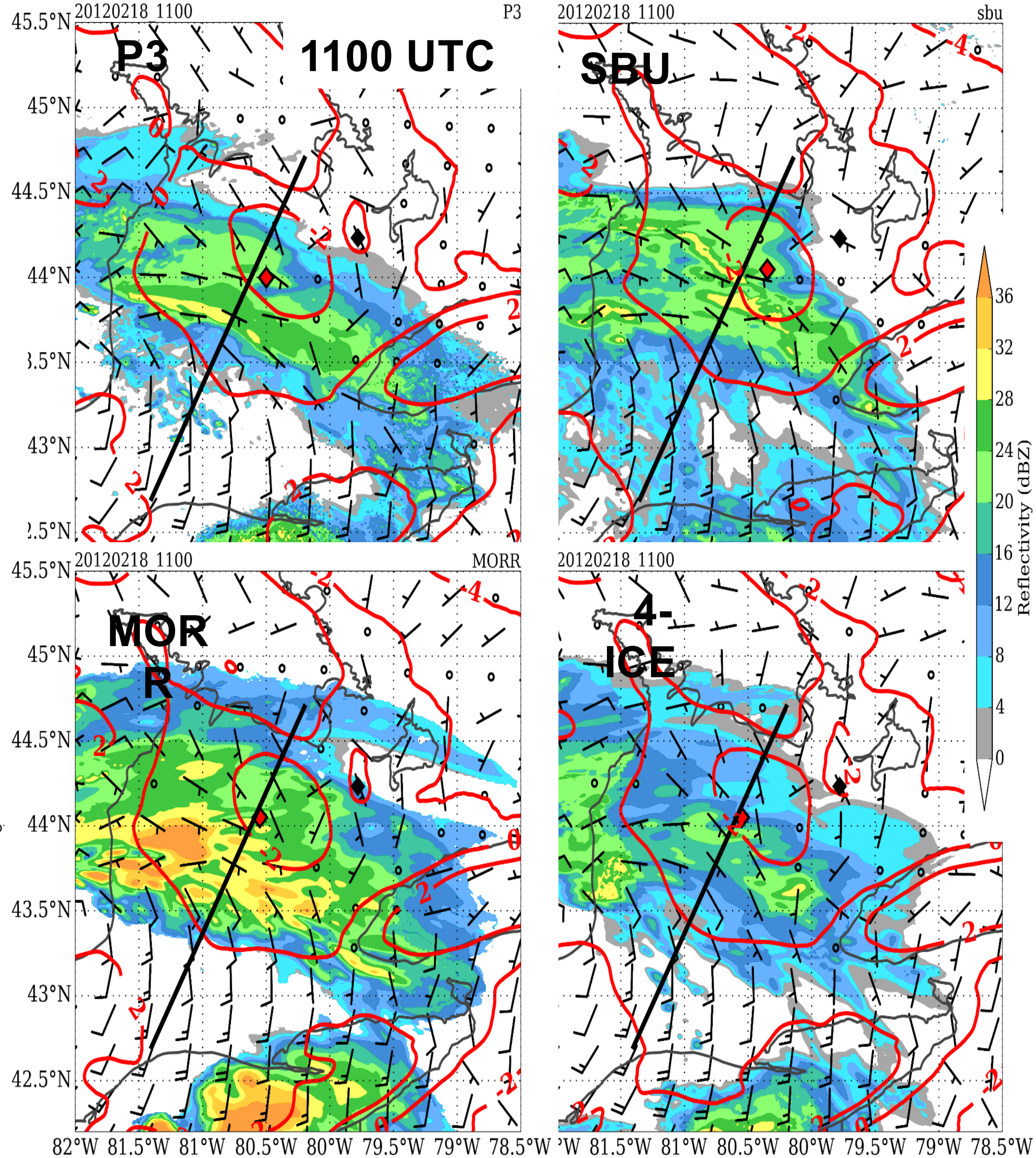
WRF Microphysical Schemes

Scheme / Acronym	Moments	Notes	Selected References
Predicted Particle Properties / P3	2	Single ice-phase category evolves freely in time and space; lookup table for N_{os}, λ_s based on mass and number concentration	Morrison et al. (2015a) Morrison et al. (2015b)
Morrison / MORR	2	Explicit prediction of number concentration and mass for each species	Morrison et al. (2009)
Goddard 4ICE / 4ICE	1	Snow mapping routine for $N_{os}(T,q_s)$ and $N_{og}(T,q_g)$	Lang et al. (2014)
Stony Brook / SBU	1	$N_{os}(T)$ by Houze et al. (1979); M-D and V-D functions of diagnosed riming factor Ri, T	Lin and Colle (2011) Lin et al. (2011)

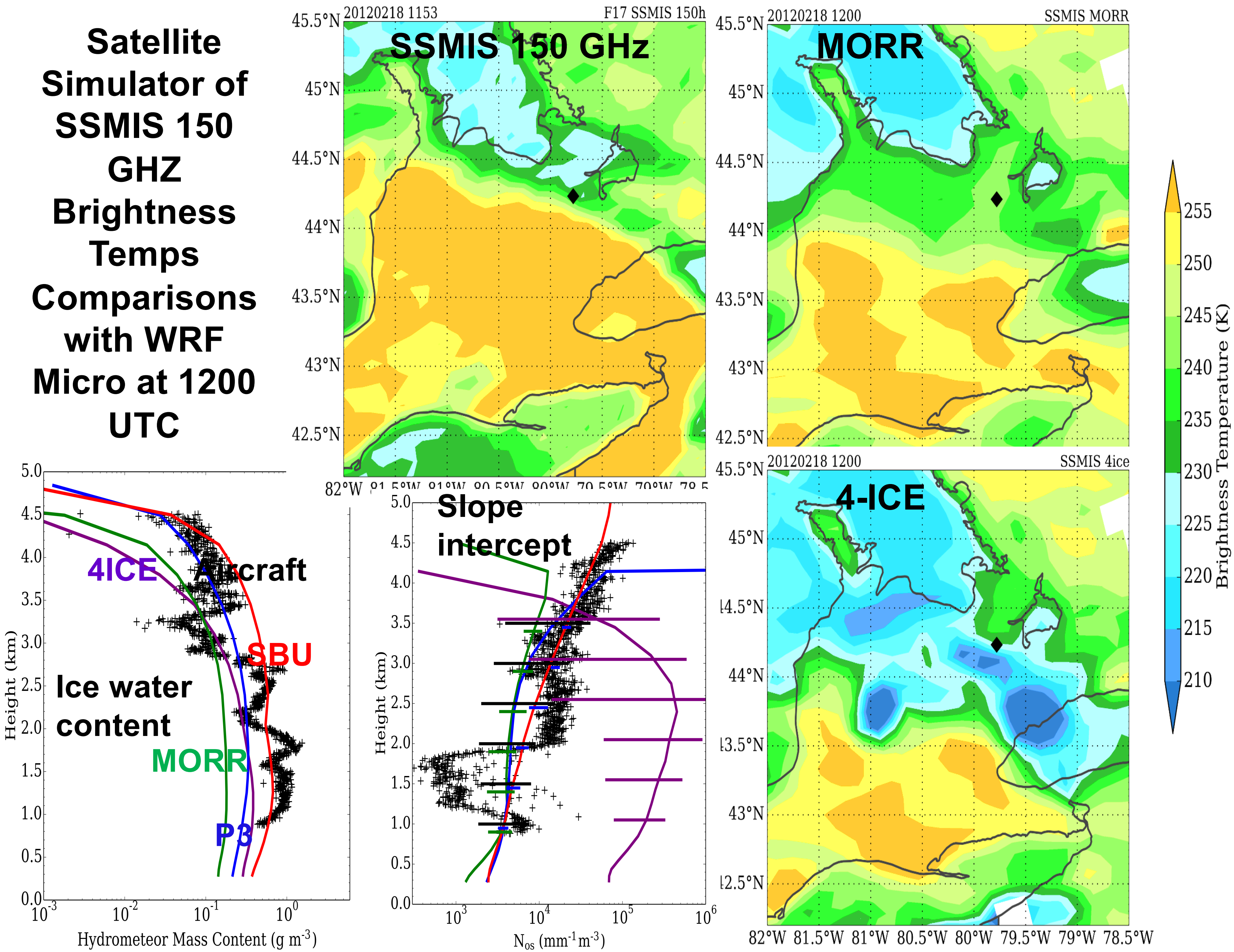
Scheme	N_{os} (m^{-4})	μ_s	ρ_s (kg m^{-3})	a_m (kg m^{-bm})	b_m	a_v (m^{1-b_v} s^{-1})	b_v
P3	$f(q_s, M_{0s})$	lookup table	predicted	$\frac{\pi}{6}\rho_S$	3	$f(R_e, X)$	$f(R_e, X)$
MORR	$f(M_{0s}, \lambda_s)$	0	100 / 400	$\frac{\pi}{6}\rho_S$	2	11.72 / 19.3	0.41 / 0.37
4ICE	$f(T, q_s)$	0	50 / 300, 500	$\frac{\pi}{6}\rho_S$	3	151.01 / 330.22, 544.83	0.24 / 0.36, 0.54
SBU	$f(T)$	0	$f(D)$	$f(T, R_i)$	$f(T, R_i)$	$f(T, R_i)$	$f(T, R_i)$

WRF Microphysical Results for Snowband

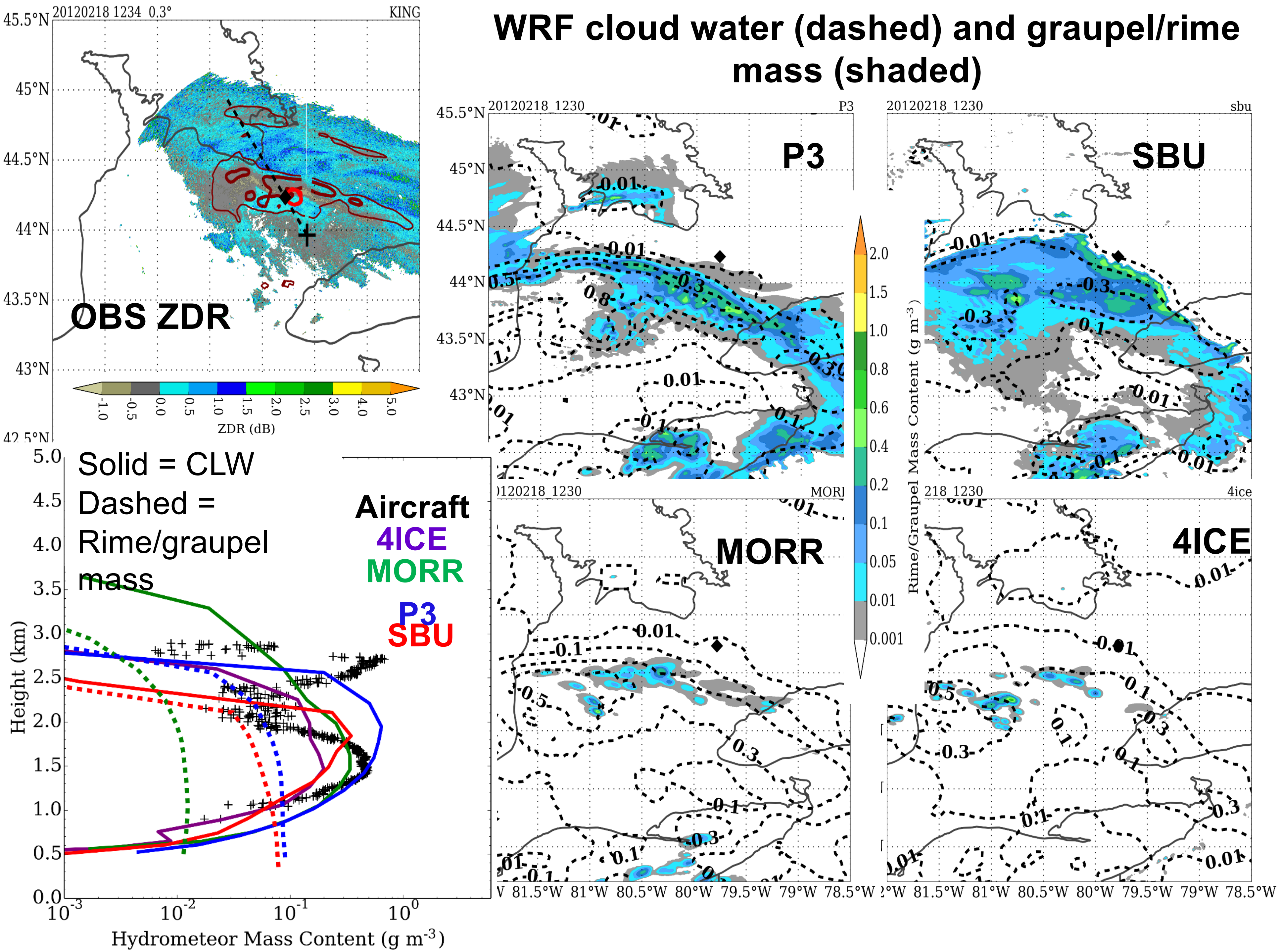




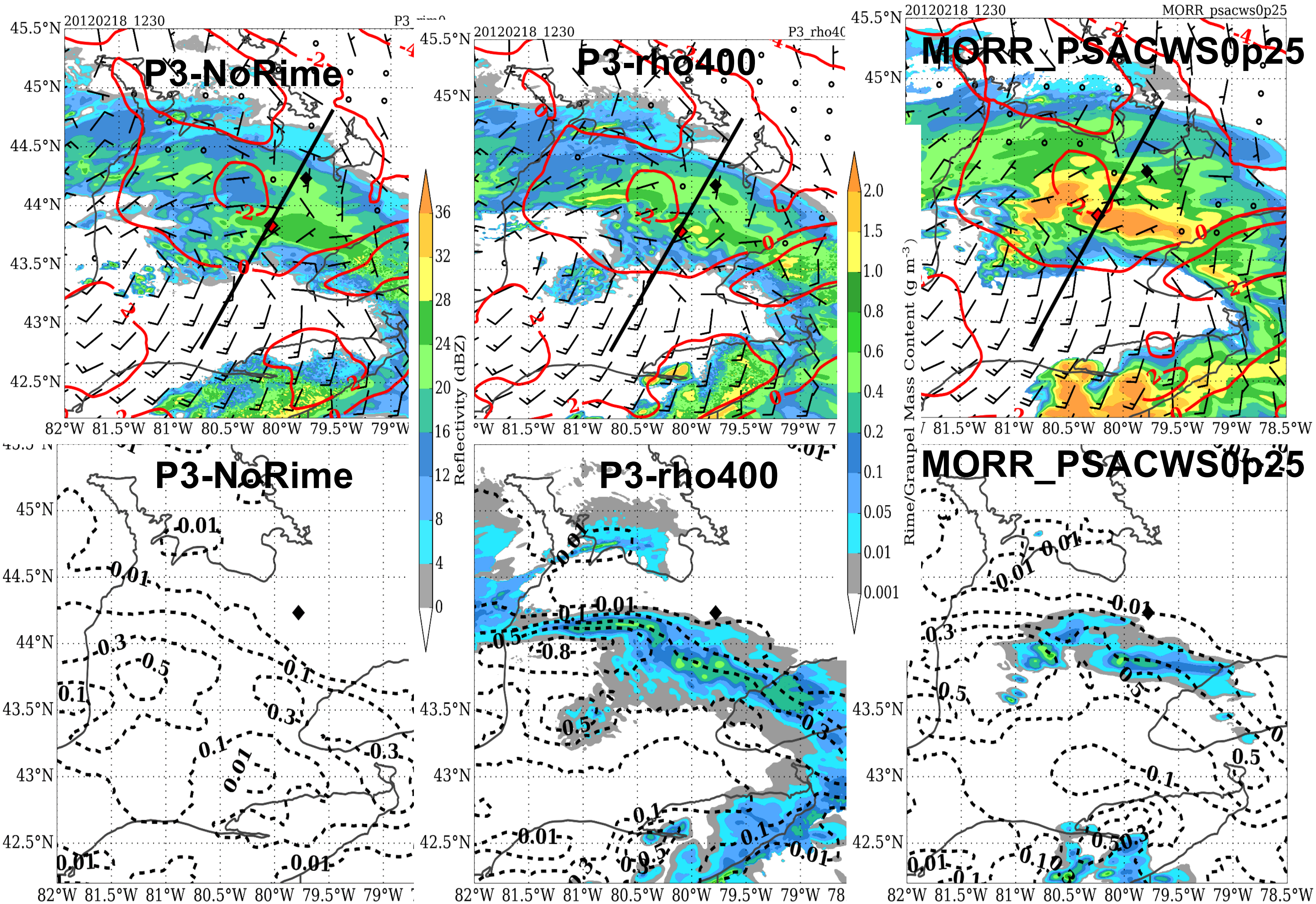
Satellite Simulator of SSMIS 150 GHZ Brightness Temps Comparisons with WRF Micro at 1200 UTC



WRF cloud water (dashed) and graupel/rime mass (shaded)

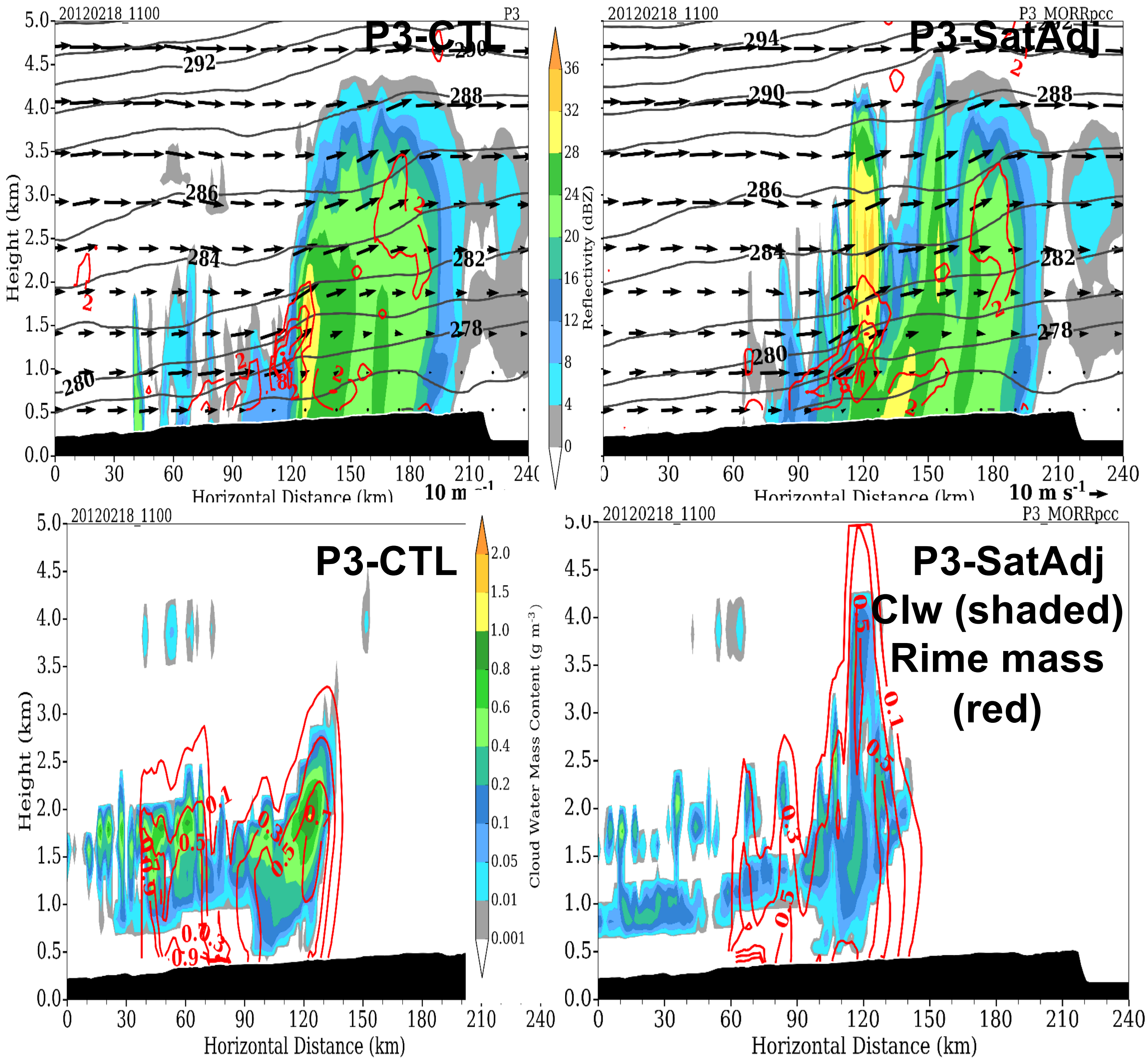


Importance of riming, MORR accretion threshold, less sensi to ice density

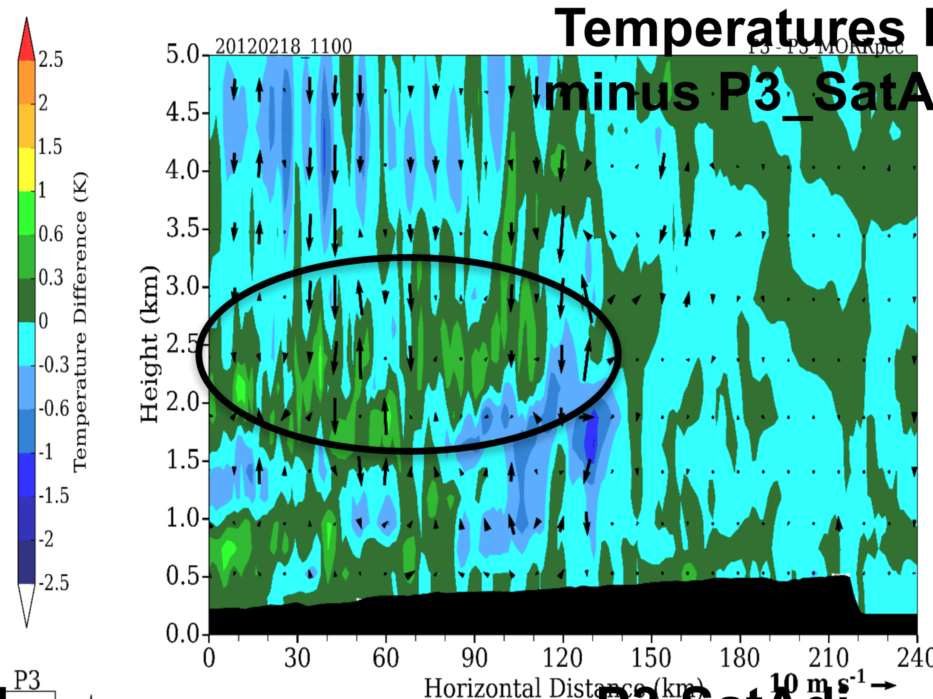


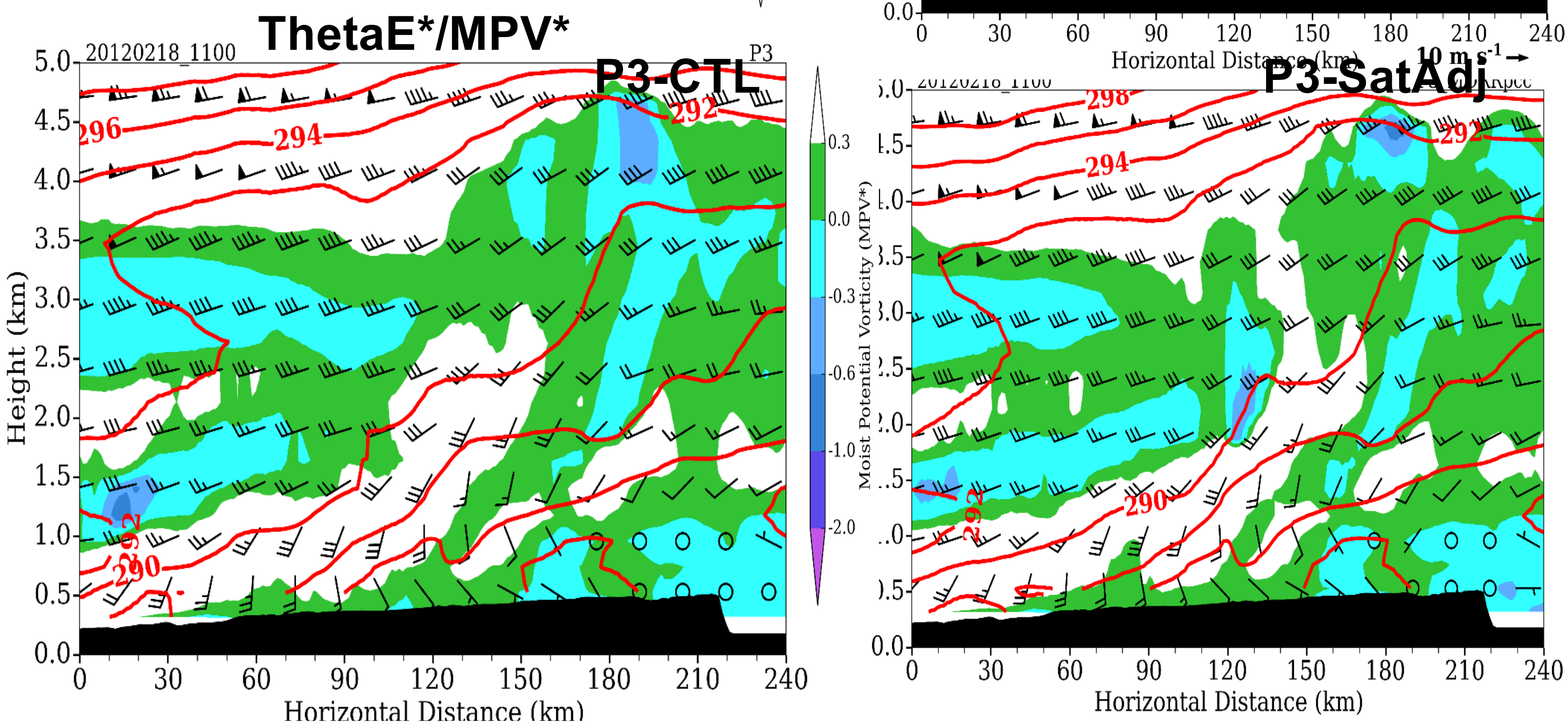
Impact of Using Saturation Adjustment Scheme in P3 Scheme:

More convective plumes near band, less organized frontal band, less cloud water upstream (more evaporation)



P3_MORRpcc has more low-level instability protruding into the band as a result of excessive evap cooling near cloud top (Grabowski and Morrison 2007)





Conclusions

• Band genesis occurred with frontogenesis in the presence of weak potential and conditional instability feeding into the region.

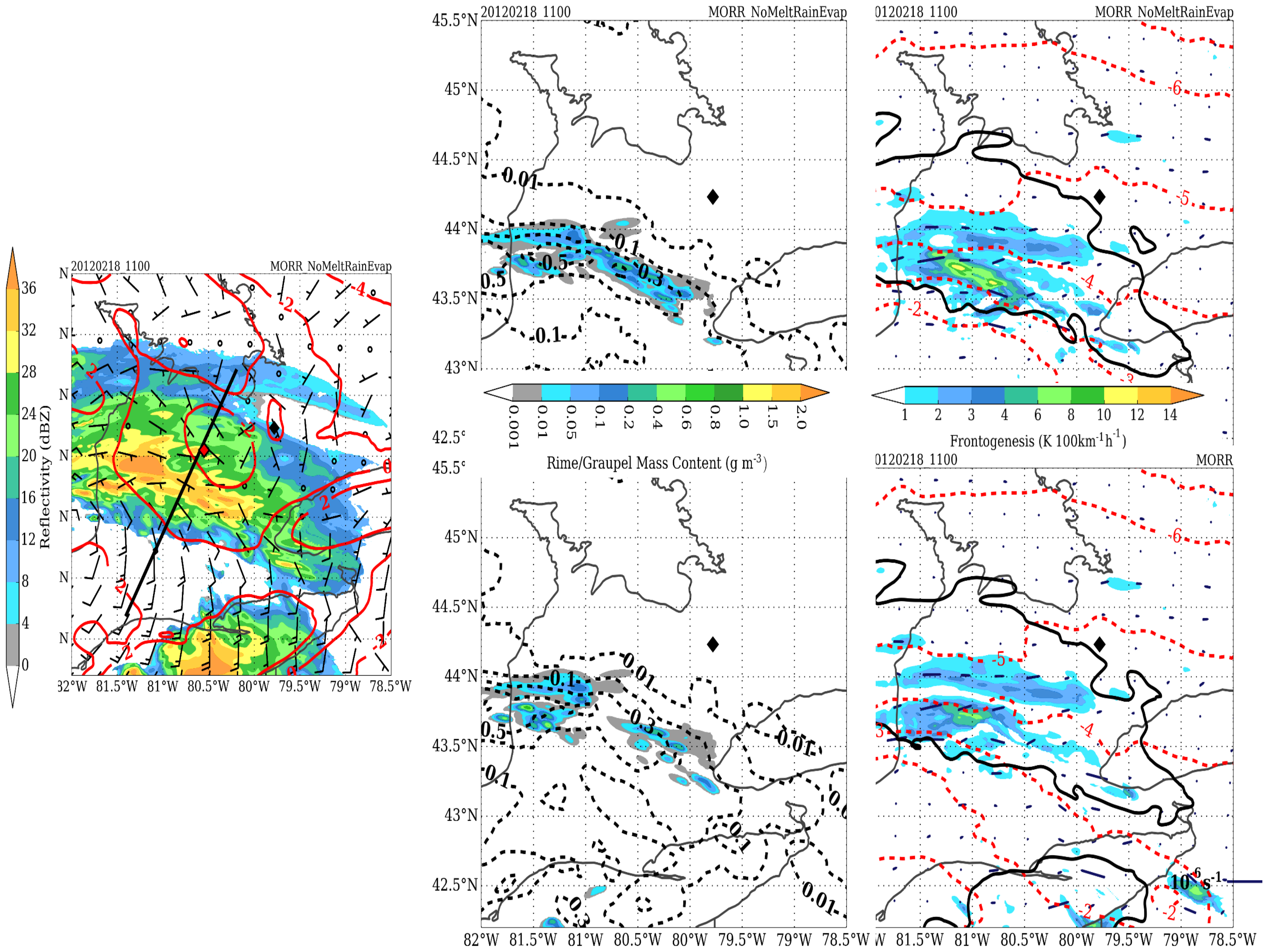
• There was significant amounts of cloud water and riming within the rising (southern) branch of the frontal circulation.

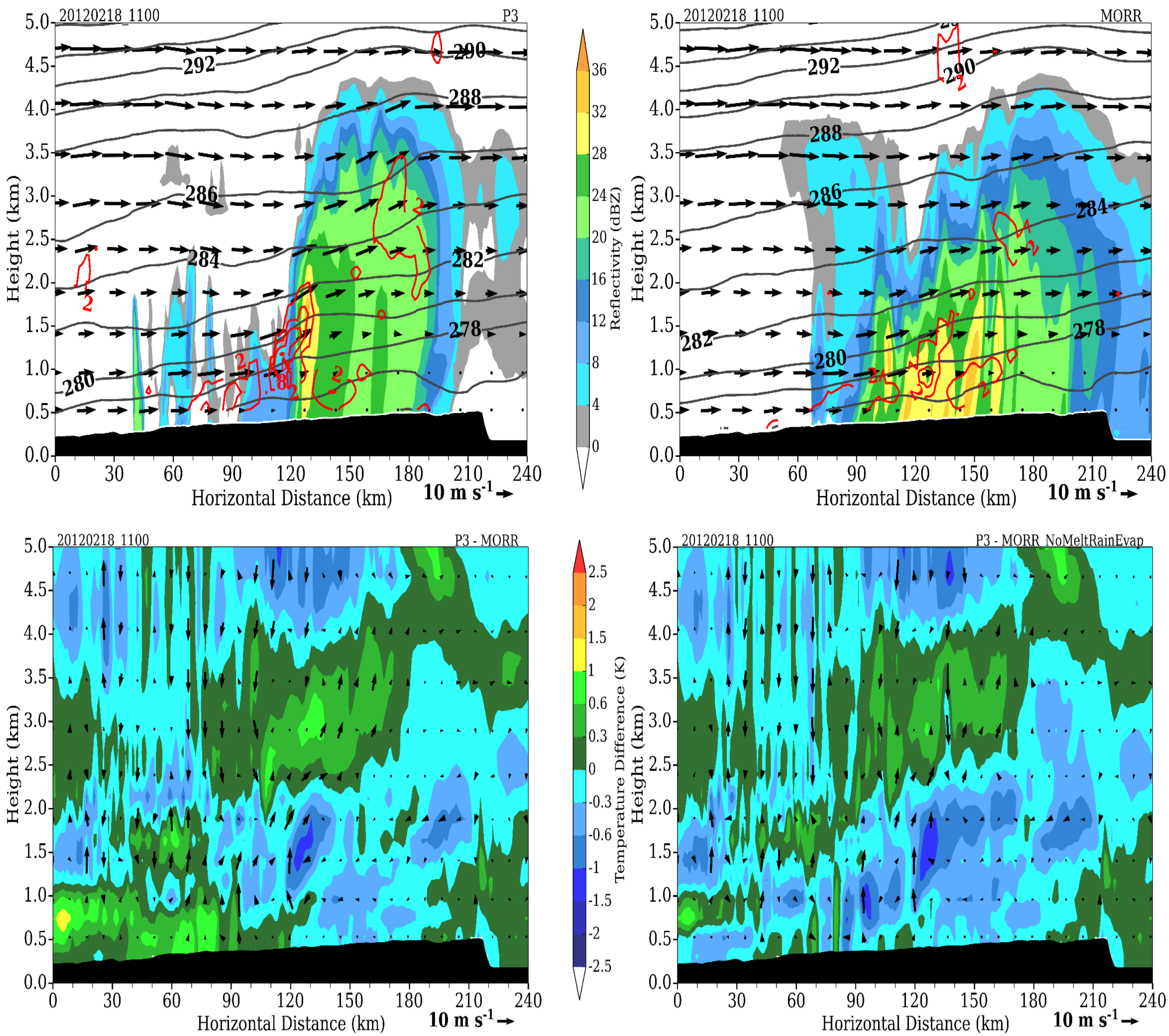
• There was relatively large sensitivity to the snowband structure/intensity to the more sophisticated bulk microphysical schemes.

• Most of the differences are related to the way the schemes partition snow and graupel. The new P3 scheme with continuous dry ice/snow to rime/graupel was most realistic. OLYMPEX results are also promising (see our Naeger et al. poster #108).

• There are other micro feedbacks: More evap w/ the sat adjustment helps destabilize and broadens convective cell response around the front; more precip cells also leads to more melt/cooling on immediate

Supplement Slides


20120218_1100
MORR_NoMeltRainEvap
Reflectivity (dBZ)
0 4 8 12 16 20 24 28 32 36
82°W 81.5°W 81°W 80.5°W 80°W 79.5°W 79°W 78.5°W
45.5°N 45°N 44.5°N 44°N 43.5°N 43°N 42.5°N
0.001 0.01 0.05 0.1 0.2 0.4 0.6 0.8 1.0 1.5 2.0
Rime/Graupel Mass Content (g m-3)
1 2 3 4 6 8 10 12 14
Frontogenesis (K 100km-1h-1)
MORR
10^6 s^-1



20120218_1100
P3
MORR
P3 - MORR
P3 - MORR_NoMeltRainEvap
Height (km)
Horizontal Distance (km)
10 m s-1
Reflectivity (dBZ)
Temperature Difference (K)